ABSTRACT

PORTABLE ENERGETIC MATERIAL DATA ACQUISITION & ANALYSIS SYSTEM

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KEY WORDS

Instrumentation, Sensors, Signal Acquisition/Analysis,
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An innovative **Portable Energetic Material Data Acquisition and Analysis System** (PEMDAAS) has been developed by Applied Research Associates personnel, while employed with the Denver Research Institute, for the Naval Surface Warfare Center (NSWC), Crane Division. This development provides the energetic material experimenter with an effective, economical, and modern-technology based system encompassing test set-up configuration, timing/firing, and data acquisition and analysis capability in one small, hardened, person-portable housing. The PEMDAAS provides signal conditioning and digitizing for piezoelectric, piezoresistive, fiber optic, temperature, voltage, and strain gage sensors. These sensor suites allow measurement of dynamic and quasi-static pressure, temperature, strain, velocity of detonation, and fragmentation velocity. This measurement capability enables the user to document and evaluate energetic material performance including free-field explosive detonations, ballistic tests, internal explosion effects, IM2105 test measurements of sympathetic detonations, slow/fast cook-offs, bullet/fragment impact tests, and other dynamic and quasi-static measurements unique to the test-and-evaluation community. PEMDAAS hardware includes a high speed timer and sequencer (for correlation of data acquisition to an event time zero), signal conditioning units, high-speed 8 to 12 bit analog-to-digital converters, and a detonator firing controller interfaced to a remotely located, up to 5000 feet, capacitor discharge firing unit which minimizes the detrimental effects of long cable lines on the firing discharge characteristics. Safety interlocks and procedures are designed into the PEMDAAS to meet explosive test site procedures and requirements. Uninterruptible Power Supply (UPS) and power conditioning ensure system operation in electrical noisy and deficient environments. Software capability includes test configuration, system control, and data analysis. System operations are computer controlled via menu selection with customized macro implementation. Detailed data analysis may be accomplished by custom macros interfaced to ASYST or Lab View for Windows analytical programs. Field ready, hard-copy data plots may be generated by conventional laser printers, or multi-color plotters. The PEMDAAS provides quality data acquisition and analysis procedures to be implemented by average technician/engineer support without the need for in-field programming expertise.

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PRESENTATION

PORTABLE ENERGETIC MATERIAL DATA ACQUISITION AND ANALYSIS SYSTEM (PEMDAAS)

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INTRODUCTION

Traditional data acquisition and analysis systems have been housed in large instrumentation trailers or in buildings with rooms dedicated to the measurement system. During the past five years ARA personnel have condensed the traditional data acquisition and analysis systems into semi-portable, multiple rack, units with features previously offered only in the larger systems. With recent advancement in digitizing and computer technologies it has been possible to develop an advanced, small, portable data acquisition and analysis system. An advanced Portable Energetic Material Data Acquisition and Analysis System (PEMDAAS) has been developed by ARA personnel, while employed with the Denver Research Institute, for the Naval Surface Warfare Center (NSWC), Crane Division to fulfill quality evaluation of explosive aging trends and reliability of explosive fuzing components. Parameters of interest include output energy of the device, unit functioning time, and directionality of the device output. In addition, the PEMDAAS is capable of free-field explosive detonations, ballistic tests, internal explosion effects, sympathetic detonations, slow/fast cook-off, bullet/fragment impact and other dynamic and quasi-static measurements unique to the test and evaluation community. This development provides the energetic material experimenter with an effective, economical, and modern-technology based system encompassing test set-up configuration, timing/firing, and data acquisition and analysis capability in one small, hardened, person-portable housing.

The PEMDAAS was designed and developed to operate autonomously in ordnance and ballistic laboratory and field site environments. However, due to its inherent flexibility, it has wide application to a variety of instrumentation measurement requirements. Because of its innovative system design and integration, components for this eight-channel system are conveniently mounted in a 18” by 24” by 17” environmentally resistant case, weighing approximately 75 pounds. The incorporation of modern hardware, custom configurations, and innovative power supply designs ensures system portability and reliable operation in remote and harsh environments. The successful blend of competent hardware and software design implementation provides quality data acquisition and analysis in a productive, cost effective manner.

SYSTEM OBJECTIVES

The objective of this system design was to provide a data acquisition and analysis unit in a small size (person portable), with a robustness for field operations in remote and hostile environments. Furthermore, the system must have capabilities similar to rack or trailer mounted instrumentation systems and be fabricated at an affordable cost. The PEMDAAS provides a broad range of control, timing/firing, and measurement capability including sequencer/timer, firing, pressure, strain, acceleration, fiber optic (velocity of detonation), and time-of-arrival information. Key system objectives included the following:

Data Acquisition---Capability for measuring, recording, and displaying data on detonation velocity, overpressure amplitude, overpressure impulse, and overpressure duration. All must be automatically converted to engineering units or be displayed in the original transducer output voltage signals.

Transducers/Signal Conditioning---Capable of processing fiber optic, piezoelectric, bridge, and direct record transducers and voltage signals. Utilizing proper safety and standard operating procedures, transducers could be interfaced to the fuzing component without removing the explosives.

Sequencing and Timing---Capable of sequencing internal and external instruments to function at the proper time in the test countdown.

Firing System---Capability of detonating conventional electric detonators with a remotely located capacitor discharge firing unit. Requirement to minimize the effects of long firing lines on the firing pulse rise time and amplitude.

Patching/Interface Panels---A patching and interface panel allows all transducer lines, amplifier channels, and A/D channels to be connected into any desired configuration. This feature also makes troubleshooting of equipment failure and/or signal line problems much easier.

Safety/Interlock Functions---Safety and interlock functions for compatibility with energetic material laboratory and range SOP's. Monitoring provided for interlock conditions during countdown sequence and automatically rendering system safe when undesirable conditions are encountered.

Uninterruptible Power Supply---An uninterruptible power supply with approximately 20 minutes of capacity eliminates loss of data due to power interruption at critical times during the test event.

System Compatibility---System compatibility with existing instrumentation hardware and software configurations used for currently used energetic material functional test systems.

DESIGN APPROACH

The design approach selected for the PEMDAAS, which meets the objectives listed above, include hardware and software with compatibility to existing energetic material functional test systems employed by the customer. Where possible, off-the-shelf components were identified and used and in other scenarios, components were modified and integrated into the system. Custom designs were implemented where necessary to meet system performance requirements. The PEMDAAS design was selected to ensure the timely and productive measurements of quality evaluation diagnostics in a safe manner for both the laboratory and field test site environments and with reduced operational support requirements. Hardware was selected based on technical merit, and subsequently modified to support performance and analysis requirements. Figure 1 depicts the PEMDAAS general architecture and configuration of the unit.

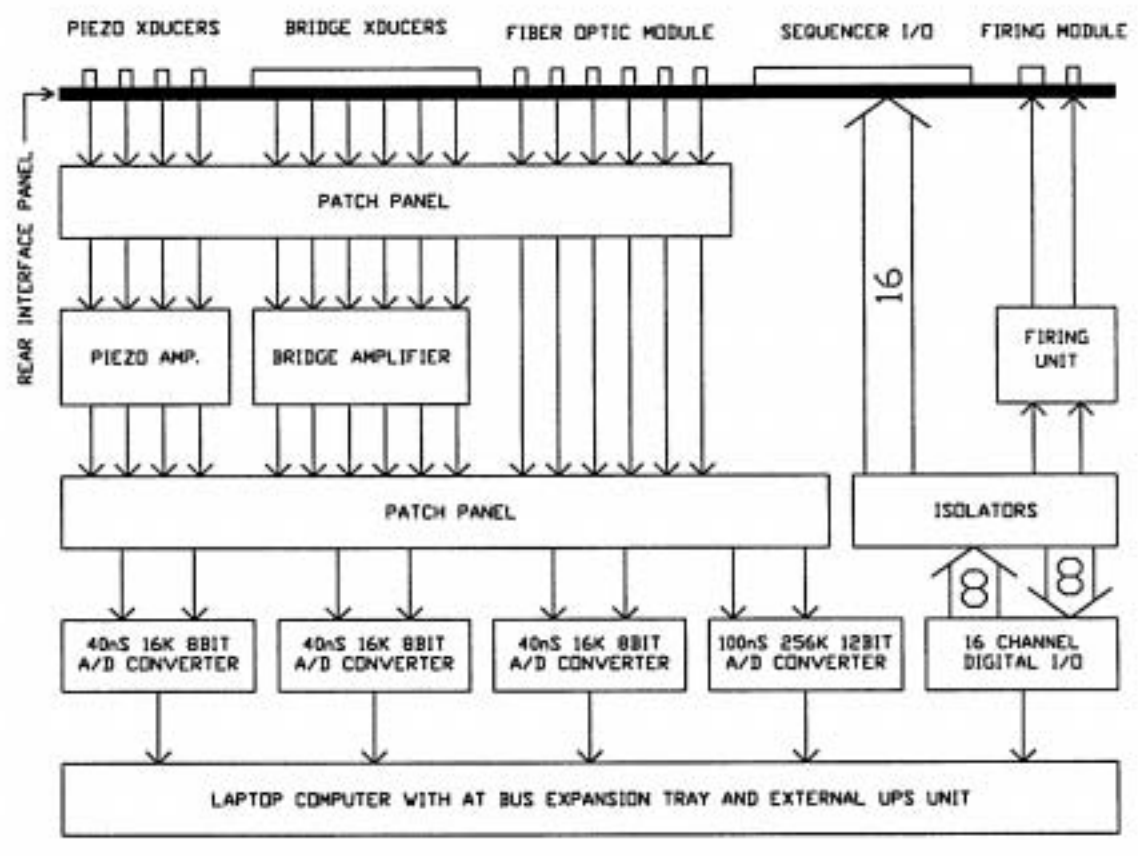

Figure 1. PEMDAAS block diagram.

The central component of the PEMDAAS is an IBM laptop computer that automatically executes the controlling software when powered-up. The computer software is the heart of the acquisition and analysis system. Functions performed by the software include:

Test Information---Transducer calibration, location, file name, and other data to serve as the test configuration table. It also provides for the automatic conversion of voltage traces into engineering units.

Sequencer Configuration---Provides control of sequencer start and stop times. It allows easy access for test-to-test configurations and changes in timing sequence for internal and external instrumentation. Sequencer data is stored to the hard disk for future reference.

Digitizer Configuration---Automatically programs the digitizers, prior to arming, with the operational parameters of voltage ranges, input coupling, sample rate, triggering levels and methods. Like the sequencer, the configuration can be stored on the hard drive for referencing digitizer set-up and/or duplicating previous set-ups. This minimizes the possibility that a change in an obscure parameter would go unnoticed and data be collected incorrectly.

Arming/Triggering of Digitizers---Status of digitizers is shown on the computer screen. Data stored in the volatile memory of the digitizers is kept active until the units are armed for the next

test. There, before each arming procedure, the software gets confirmation from the user before arming.

Data Collection---Data is automatically transferred to the hard disk post-event, or files may be manually transferred to disk as specified by the user. The automatic feature prevents accidental loss of data due to operator error.

Data Storage---Both hard disk and floppy disks. Data may be stored in ASYST or in ASCII formats.

- **System Hardware**

The hardware was mounted into a 18" by 24' by 17" weather/dust resistant case as shown in Figure 2. This figure shows the PEMDAAS in a shipping condition, i.e., the computer lid closed, and the fiber optic signal conditioning/checker and firing unit mounted in the storage compartments located on the control panel. The case with hardware installed weighs approximately 75 pounds. and is easily carried by two people. The hardware selected for the PEMDAAS is listed below:

Figure 2. Hardware mounted in weather/dust-resistant case.

Computer System---486 DX2 notebook computer operating at 50 MHz, 4 MB RAM, 540 MB hard disk, 1.44 MB floppy disk, color VGA and six slot AT bus expansion unit.

Analog to Digital Converters---Eight digitizer channels were provided in the PEMDAAS. Two of the eight channels provide 12-bit resolution, and 100 nanosecond maximum sample rate and 256 KB memory/channel. The other six channels are 8-bit systems with 40 nanosecond sample rates and 16 KB memory/channel. All eight channels are software controllable for full scale voltage ranges, sampling speed, and triggering modes, including pre-trigger memory sizes.

Signal Conditioning---Six channels of bridge signal conditioning amplifiers perform the function of processing the strain gages, piezoresistive transducers, and other voltage generating transducers. Maximum frequency response is 200 Khz with switch selectable low pass filters to prevent digitizer aliasing problems. The amplifiers are equipped for shunt calibration, offset, balance adjustments, and adjustable gain. Test jacks provide for front panel excitation and amplifier output calibrations. The excitation power supply is adjustable from 0.1 to 15 volts.

A four-channel piezoelectric amplifier system provides the constant current excitation, 180 Khz bandwidth, two second low frequency time constant, bipolar 10-volt output, and an output impedance of less than 100 ohms for piezoelectric transducers used for blast and shockwave measurements. A meter monitors the condition of the gauge/cable assembly.

Six channels of remotely located fiber optic signal conditioning satisfies the requirements for the fiber optic sensors used for velocity/time-of-arrival information. The fiber optic conditioning system is designed to be placed within 100 feet of the test event (assumes use of plastic fiber optic sensors). The light-to-voltage conversion is performed and the voltage signals are then interfaced to line drivers for driving up to 5000 feet of coaxial cable. This custom designed system provides a 100 nanosecond rise time. A nonlinear amplifier design enhances the dynamic range by reducing the gain as a function of the light level detected. A light pulse generator was provided with the system to allow the user to verify the operation of the fiber optic system pre-event by insertion of 1 Khz light pulses into the fiber optic sensors.

Firing Power Supply---An adjustable, remotely located, capacitor discharge conventional electric detonator firing unit was custom designed to fulfill explosive initiation requirements. The local (relative to the test bed) generation of the firing pulses eliminates the energy loss associated with firing conventional detonators through long lines. Many munitions Sequence and Arming (S/A) simulation tests require firing waveforms and energy levels compatible with normal S/A initiation. Using this firing systems fulfills this requirement.

The firing control unit, mounted in the PEMDAAS housing is configured with a safety key switch which provides a short on the firing line when the switch is in the safe mode. A meter shows the voltage level of the capacitor, and an adjustment knob allows the output to be set to the desired voltage level . Arming and firing functions can be performed manually or by computer sequence control. The maximum distance between the control system and the remote unit is 5000 feet. Maximum energy is three joules with 250 volts of excitation.

Timing/Sequencer---16 channels of digital I/O interfacing meets the requirements of control and safety interlock/signal monitoring. Eight digital output channels provide sequencing control capabilities for internal and external equipment (such as cameras, lighting systems, firing supplies, solenoids, and amplifier channels). Each channel's start and stop times, relative to event time zero, are set by the user through on-screen programming software. Eight digital input channels provides the capability to monitor safety signals/interlocks while a test is being performed. The input channels can be on-screen configured.

Power Supply/Conditioning---The PEMDAAS is operates from 120 VAC, 60 Hz power. Line filters provide spike and surge protection, and an Uninterruptible Power Supply (UPS) provides 20 minutes of capacity to eliminate loss of data due to power interruption at critical times during the test event. The PEMDAAS can be modified to operate from battery power with little effort.

Interfacing/Patching---Transducer, sequencer, firing, and power lines connect to the interface panel. A patch panel allows all transducer lines, amplifier channels, and A/D channels to be connected into any desired configuration. This configuration makes troubleshooting of equipment failure and/or signal line diagnostics operationally simple to accomplish.

In addition, a 100 foot cable reel assembly provides for easy deployment of the cabling between the fiber optic signal conditioning and the low voltage firing module. Figure 3 shows the cable assembly with the modules attached.

Figure 3. Remote modules attached to 100 feet of cable.

- **System Software**

The software provided with the PEMDAAS provides configuration, acquisition, control, data reduction, and display capability. The software is in menu format, with macro control/execution of functions.

The main menu is activated automatically during power up. The choices displayed in the menu are: Configure Data, Configure Digitizers, Configure Sequencer, Acquire Data, Reduce Data,

Display Channels, and Exit to DOS. When the menu item is selected, the appropriate program is executed and upon exit of that program, the main menu is returned to the screen for the next selection.

The **Configure Data** program accepts from the user information about the test such as: Data File Name, Transducer Type, Transducer Calibration (expressed as millivolts per engineering unit), Distance from Ground Zero, and Comments. This information is used to convert the voltages recorded by the digitizers into engineering units (such as pounds per square inch or degrees). It also uses the distance information in determining velocities.

The **Configure Digitizer** program controls the digitizer operating parameters. Individual channel parameters are voltage input range and input coupling. Card selectable values are sample rate, sample size, trigger level/coupling, and pre-trigger amount. This data is stored in a file with a user selected name and the latest digitizer configuration displayed is the one used for the test event.

The program labeled **Configure Sequencer** controls the event sequence start and stop times, and the original countdown sequence start point is selected. Each interlock channel is monitored and its effect on the firing sequence (fire only when input high, fire only when input low, ignore interlock) is software selectable. This configuration table is stored to a user selected file name.

Data acquisition is accomplished through the **Acquire Data** menu. This routine loads the configuration data, digitizer set-up parameters, and the sequence/interlock information, and initiates/programs the digitizers accordingly. The user has the option of using the file names from the configuration table or providing new ones. The user also has the option of automatically saving the data to the hard disk post test, or the user may choose to manually save post event, or not to save data at all. The display shows the interlock status and safety condition (high, low, or ignore) of each channel along with a summary of the safety interlock status.

Reducing data is accessed through the **Reduce Data** routine. This program provides display and manipulation capabilities. Data can be viewed and manipulated in the **"VIEW DATA"** portion of the software. User selected cursor positions can be read out and data expanded to show any portion of the data. Mathematical calculations can be performed as manipulation of the various plotting parameters, such as, axis labels and scales.

The final two software menu choices are **Display Channels** and **Exit to DOS**. The Display-Channels option provides a live view of any of the eight channels on the computer screen for review and checkout purposes. The Exit-to-DOS option terminates the main menu program and gives the user control through the DOS environment.

System Applications---Figure 4 shows the PEMDAAS ready for fielding. As shown this system was designed to provide fast and accurate measurement and analysis capability for quality evaluation of energetic material. Systems of this type have traditionally been used by ARA personnel in energetic materials performance appraisals to measure incident/reflected pressures, hard target assessment studies, early time disassembly diagnostics, temperature-time histories, warhead fragment velocity, and sequence and arming (fuze train) function times. It is also well

suited for terminal ballistic applications including the measurement of breech block pressures, reactive armor pressures and velocities, projectile velocity and penetration profiles. The PEMDAAS flexible and versatile design is also well suited for multi-disciplinary research laboratory diagnostic applications.

Figure 4. PEMDAAS ready for fielding.

SUMMARY

In summary, the PEMDAAS provides a competent, cost effective instrumentation system incorporating capabilities of traditional instrumentation systems by the integration of innovative new hardware and software systems. These systems combined with procedures tailored for laboratory and field test sites provide a comprehensive measurement and analysis system. The integration of modern hardware and customized software in a portable, 75 pound package provides for stand-alone operation in remote and harsh environments.

The major benefits of this system's innovation and integration are high data quality with decreased acquisition and operational costs. The system provides complete control of the test site for timing, sequencing, firing, signal conditioning, signal recording and data analysis. In addition, the PEMDAAS addresses the complete test site requirements of power quality, safety, and operational issues.